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AUTHOR Ayers, Caroline L.
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ABSTRACT

Presented is a descriptive account of guided design, an educational strategy in which students work together in small groups to solve open-ended problems designed to provide experience in applying the subject matter content of a course. The essential elements of this instructional strategy are described, and the instructor's role clarified as "professional consultant helping to find the solution to a problem." Project titles and a description of the related subject matter are provided for several guided design projects in developmental natural science and general chemistry. (CS)

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GUIDED DESIGN: A MOTIVATIONAL TOOL

Caroline L. Ayers, Department of Chemistry, East Carolina University, Greenville, NC 27834

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GUIDED DESIGN: A Motivational Tool

Caroline L. Ayers, Department of Chemistry, East Carolina University, Greenville, NC 27834

Guided Design is an educational strategy developed by Charles Wales and Robert Stager[1] in which students work together in small groups to solve open-ended problems designed to provide experience applying the subject matter content of a course. Although originally used by Wales in the freshman engineering program at the University of West Virginia, it has been adapted by others to such diverse disciplines as English, Nursing, Philosophy, Political Science, Drama, Business, and Chemistry. It has been used at all levels from secondary schools to graduate and professional schools.

In Guided Design, students are presented a problem and are guided in their search for a solution by a set of instructions which imitate the problem-solving strategies of professionals in the discipline. The solution of the problem requires the use of portions of the subject matter for the course. This provides the motivation for learning the subject matter of the course. Guided Design is most practical for classes of less than 40 students. Groups of four to six students work on the projects during the class period. Homework assignments in the subject matter parallel the project content. The assignments, which may include readings, questions and problems, provide background information necessary to the solution of the problem addressed in the project. (All of the subject matter assignment need not be used directly, but some of the ideas should be pertinent to the project.) The relevance of the projects to the students' interests and experiences is an essential feature of a successful project. Project topics must be chosen carefully to necessitate application of the subject matter as well as be timely. If the students do not see the relevance of the project, interest wanes and the motivation to learn the subject matter, which in my opinion is one of the strongest features of this instructional method, is lost.

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Through the appropriate design of the projects and through the guidance given the groups as they work on the projects, the instructor models the approach of a professional in problem solving in the discipline. This is also an important feature of Guided Design. The steps must be carefully and clearly outlined so that students can model the strategies of successful problem solvers. Although the order of steps will vary depending on the project, there are several essential elements which should be included in guiding students to a successful solution.

(1) Identify the Problem and State the Goal. Although this seems obvious, it is surprising how frequently students fail to recognize the importance of this step. Because of unclear or confusing goals, much effort can be spent in unproductive endeavors. Developing a clear and concise statement of purpose is essential to problem solving and should be the first step in the project.

The order of the next four steps will vary depending on the project.

(2) Gather Information. Examples of this would be reading/question/problem assignments pertinent to the project, the collection of data from a lab experiment, and obtaining data from references.

(3) Generate Possible Solutions. Better known as brainstorming, this step involves thinking of possible approaches or solutions without regard to their practicality. Prejudging ideas may result in overlooking good solutions which on the surface appear inappropriate.

(4) State Constraints, Assumptions and Facts. The constraints, the bounds within which one must work to achieve a solution, will affect the choices of solution. Assumptions simplify the problem and make it amenable to solution. The facts are the known quantities. They may be derived from the problem statement or obtained from the information gathering step.

(5) Evaluate and Make a Decision. Considering the constraints, assumptions and facts, evaluate the possible solutions. Decide which approach seems most likely to yield a solution to the problem.

After making a decision concerning the method of approach, implementation of the method, developing and reporting the solution ensue.

(6) Analysis. Generate a step-wise plan for the solution chosen. Gather the necessary information and implement the plan.

(7) Synthesis. Create a unified solution based on the solutions to the steps used in the analysis.

(8) Evaluate Solution. Carefully consider the proposed solution to insure that it satisfies the goal and is consistent with the constraints. Economics, safety, legality and morality of the solution should also be examined at this point.

(9) Report the Results. Write a final report describing the solution and the approach used in achieving a solution. Make recommendations based on the solution. (For chemistry projects, a good format for reports is given by Wittcoff in his book on Industrial Organic Chemistry and College Science Teaching.[2])

When Guided Design is used in the class, the role of the instructor changes from the "oracle from which all information and truth springs" to "professional consultant helping find the solution to a problem." This can be quite a shock to students and a difficult adjustment for the instructor as well. The primary role of the instructor is to prepare written instructions to guide the students through each step of the project so that they can find the solution for themselves.

The instructor needs to be available to clarify instructions and to keep students working toward the goal they have established while at the same time allowing them as much freedom as possible to pursue different paths to the solution. Sometimes students learn more from their mistakes than from a "correct" solution. As instructor, your responsibility is to guide them to see the error of incorrect approaches rather than simply tell them that another approach works while theirs will not. As you might imagine, this is initially difficult for both instructor and students; but as students recognize that most problems they face have no unique solution, they develop self-confidence in their ability to solve the problem and depend less on the instructor for help.

Another important characteristic of Guided Design has already been alluded to, the lack of a unique solution to complex problems. Although most, if not all, students in a class will arrive at the same conclusion concerning

the solution to a problem, this is not necessarily so. In some projects the probability of reaching different conclusions is quite large. Initially students find this disquieting. Being accustomed to a "black and white world," particularly where science is concerned, they find it difficult to accept that different conclusions can be drawn from the same data. This is, of course a characteristic of complex problems and provides the opportunity to discuss how alternative interpretations of data can lead to different conclusions and how constraints and assumptions affect the interpretation of data.

As mentioned earlier, Guided Design has been used by several people in the instruction in chemistry courses from the preparatory and general chemistry levels to physical chemistry and industrial chemistry at the junior-senior level. Although my experience using Guided Design has been limited to physical chemistry, I feel it would be of more interest to participants in the $2YC_3$ to describe its use in preparatory and general chemistry courses.

Dr. Patricia Redden has been using Guided Design for 3 years in the preparatory science course at St. Peter's College in Elizabeth, NJ.[3] Since a large number of students had been unsuccessful in their beginning chemistry and biology courses, a program to develop study skills appropriate to these areas was instituted. Dr. Redden felt that Guided Design would be an effective instructional method for their Developmental Natural Science course. She developed 5 projects which involved study skills and concepts from both biology and chemistry. The titles of the projects and subject matter or description of content are given in Table 1.

Dr. Patrick Hoggard of the Polytechnic Institute of New York has been using Guided Design in his General Chemistry Course for several years.[4] He has continued to develop projects so that he now has 11 projects on a variety of topics (see Table 2).

TABLE 1. GUIDED DESIGN Projects for Developmental Natural Science (Dr. Patricia Redden, St. Peter's College, Elizabeth, NJ)

Project Titles	Subject Matter/Description
Study Skills	Investigate own problems; find available services
The Scientific Method	Students attempt to solve commuting problem
The Case of the Decaying Statues	Air pollution and stoichiometry; acid rain
Human Resources and Water Pollution	pH, Henry's Law
To React or Not to React	Atomic structure, nuclear chemistry

TABLE 2. GUIDED DESIGN Projects for General Chemistry (Dr. Patrick Hoggard, Polytechnic Institute of New York, Brooklyn, NY)

Project Titles	Subject Matter
Oklahoma Story	Stoichiometry
Is Salt the Proper Seasoning for the Streets of New York?	Colligative properties
Element from Outer Space	Periodic properties
Disintegrating Statues	Gases, air pollution
Distant Object	Atomic spectroscopy and the hydrogen atom
The Smell of Things to Come	Molecular structure
Would you Like to Come Up and See me Etching?	Electrochemistry
Bloody Equilibrium	pH, ionic equilibrium
Water for Abu Kutar	Thermodynamics (desalination)
Ammonia Mania	Kinetics, equilibrium
Candy Man	Equilibrium

Dr. J. C. Norman has used Guided Design in an interdisciplinary chemistry-physics course at the University of Wisconsin at Green Bay.[5] He has a project entitled "Wood Alcohol" which utilizes concepts in thermodynamics and equilibrium. (His other projects primarily involve concepts from physics.)

When you look at the number of projects used by Redden and Hoggard, you may feel that Guided Design is beyond your reach because of limited time to develop projects for use in your classroom. Although that might be true if you converted your entire course to the Guided Design format, one of the desirable features of Guided Design is that this is not necessary. In fact, many people use only one or two projects in their course, the remainder being a more traditional lecture format.

If you are interested in using Guided Design, I would recommend starting with a single short project, either one written by yourself or one written by an experienced Guided Design user. In that way you can learn how Guided Design works in your classroom without a large expenditure of either your effort or instructional time. (By using only one project, you will not need to make the extensive preparation required of those who convert their entire course to Guided Design--preparing self-study materials in addition to the Guided Design projects.)

If you are interested in using Guided Design or want to learn more about Guided Design (how it works, how to write projects, etc.), I would strongly recommend your obtaining a copy of "Guided Design" by Charles E. Wales and Robert A. Stager.[6] This is the Guided Design users' handbook. Several Guided Design projects are included in the book along with detailed information about how to write projects and how to organize a Guided Design course. This book can help you decide whether Guided Design is appropriate for your course. At

the end of the book is a list of users of Guided Design compiled by Wales and listed by discipline. Most Guided Design users would be happy to answer specific questions you may have concerning Guided Design. The references cited earlier[3,4] will give more specific information about the use of Guided Design in introductory chemistry courses. If you would like a copy of a specific Guided Design project, please contact the author concerning the availability of a copy of the project.

Personally, I have enjoyed using Guided Design in my physical chemistry course. Although it has been hard work for both the students and myself, most students have felt that they profited from the Guided Design format. Guided Design allows the instructor to fill a different role in the lives of students, the role we in theory espouse--colleagues in the quest for knowledge. Guided Design also encourages a discussion of the significance of assumptions and constraints in the interpretation of data. Additionally an opportunity is provided for appreciation of the interrelation of science and such diverse disciplines as economics, ethics, social values and how these areas affect the interpretation of scientific data. Most students indicated that the Guided Design format demanded more time, energy and self-discipline than a lecture course. In spite of this, most students felt that seeing the applicability of the subject matter and working with other students had been a valuable experience.

Footnotes

1. Wales, C. E., and Stager, R. A., Engineering Educ., 62, 456(1972).

2. Witcoff, H., "Industrial Organic Chemistry and College Science Teaching," 1978. (Manual for NSF Chautauqua Short Courses taught by Dr. Wittcoff)

3. Redden, P. A., and Petriello, R. P., J. Chem. Educ., 57, 712 (1980).

4. Hoggard, P. E., J. Chem. Educ., 57, 299 (1980).

5. Norman, J.C., and C. R. Rhyner, "Energetics", University of Wisconsin-Green Bay, Green Bay, 1976.

6. Wales, C. E., and Stager, R. A., "Guided Design," West Virginia University, Morgantown, 1977. (Available from Dr. Charles Wales, Director of Freshman Engineering, University of West Virginia, Morgantown, WV 26506 at a cost of $5.)